JC07 Rec'd PCT/PTO 26 NOV 2001

FORM PTO-1390
(REV 10-94)

U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
10873.711USWO

U S APPLICATION NO (If known, see 37 C F R 1 5)
to be assigned 09/980109

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/03480	May 30, 2000	May 31, 1999

TITLE OF INVENTION

OPTICAL INFORMATION RECORDING METHOD, OPTICAL INFORMATION RECORDING APPARATUS AND OPTICAL INFORMATION RECORDING MEDIUM

APPLICANT(S) FOR DO/EO/US

Narumi et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US)
6. [X] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [X] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [X] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment, Mark-up copy of claims, Abstract.
    [ ] A SECOND of SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information: form PCT/RO/101, form PCT/ISA/210, form PCT/IB/301, form PCT/IB/304, form PCT/IB/308, form PCT/IPEA/401, form PCT/IB/332, form PCT/IB/338, form PCT/IPEA/409.

JC03 Rec'd PCT/PTO 26 NOV 2001

U.S. APPLICATION NO (If known, see 37 C F R 1 5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
to be assigned 09/980109	PCT/JP00/03480	10873.771USWO

17. [X] The following fees are submitted:				CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(a) (1)-(5)): Search Report has been prepared by the EPO or JPO........**$890.00** International preliminary examination fee paid to USPTO (37 CFR 1.492(a)(1))........**$710.00** No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))........**$740.00** Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(3)) paid to USPTO........**$1040.00** International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)........**$100.00**					
ENTER APPROPRIATE BASIC FEE AMOUNT =				$890	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	24 -20 =	4	X **$18.00**	$72	
Independent claims	6 -3 =	3	X **$84.00**	$252	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$260.00**	$0	
TOTAL OF ABOVE CALCULATIONS =				$1214.00	
Reduction by 1/2 for filing by small entity, if applicable. Small entity status is claimed pursuant to 37 CFR 1.27				$0	
SUBTOTAL =				$0	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f). +				$0	
TOTAL NATIONAL FEE =				$1214.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$40.00	
TOTAL FEES ENCLOSED =				$1254.00	
				Amount to be: refunded	$0
				charged	$0

a. [X] Check(s) in the amount of $1214.00 and $40,00 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ________________ in the amount of $ ____________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 13-2725.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO
Douglas P. Mueller
MERCHANT & GOULD
P.O. Box 2903
Minneapolis, MN 55402-0903

SIGNATURE: [signature]

NAME: Douglas P. Mueller

REGISTRATION NUMBER: 30,300

Int'l Appln No.: PCT/JP00/03480
Docket No.: 10873.771USWO

09/980109

JC03 Rec'd PCT/PTO 26 NOV 2001

S/N unknown

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Narumi et al.	Docket No.:	10873.771USWO
Serial No.:	unknown	Filed:	concurrent herewith
Int'l Appln No.:	PCT/JP00/03480	Int'l Filing Date:	May 30, 2000
Title:	OPTICAL INFORMATION RECORDING METHOD, OPTICAL INFORMATION RECORDING APPARATUS AND OPTICAL INFORMATION RECORDING MEDIUM		

CERTIFICATE UNDER 37 CFR 1.10
'Express Mail' mailing label number:
Date of Deposit: November 26, 2001
I hereby certify that this correspondence is being deposited with the United States Postal Service 'Express Mail Post Office To Addressee' service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, P.O. Box 2327, Arlington, VA 22202.

By: [signature]
Name: Chris Gordon

PRELIMINARY AMENDMENT

Box PCT
Assistant Commissioner for Patents
Washington, D. C. 20231

Dear Sir:

In connection with the above-identified application filed herewith, please enter the following preliminary amendment:

IN THE ABSTRACT

A new abstract page is supplied to conform to that appearing on the publication page of the WIPO application, but the new Abstract is typed on a separate page as required by U.S. practice.

IN THE SPECIFICATION

A courtesy copy of the present specification is enclosed herewith. However, the World Intellectual Property Office (WIPO) copy should be relied upon if it is already in the U.S. Patent Office.

IN THE CLAIMS

Please amend claims 7-11 to read as follow:

7. (Amended) The optical information recording method according to claim 1, wherein amounts of correction of the leading and trailing edge positions of the recording pulse are determined by recording and reproducing a predetermined recording test pattern before recording the information.

8. (Amended) The optical information recording method according to claim 1, wherein a predetermined reproduction test pattern is recorded on the optical information recording medium so as to determine reproduction conditions of the information by reproducing the reproduction test pattern before reproducing the information.

9. (Amended) The optical information recording method according to claim 1, wherein information is further represented by the leading and trailing edges of the unit recording area.

10. (Amended) The optical information recording method according to claim 1, wherein power of the laser beam is lowered to a bias level in a portion between a first recording pulse for recording a first unit recording area and a second recording pulse for recording a second unit recording area when the first and second unit recording areas, each having a different mark width other than zero, are recorded continuously as the unit recording areas.

11. (Amended) The optical information recording method according to claim 1, further comprising selecting whether the information is represented by a width of the unit recording area in accordance with a type of information.

Please add new claims 20-24

20. (New) The optical information recording method according to claim 4, wherein amounts of correction of the leading and trailing edge positions of the recording pulse are determined by recording and reproducing a predetermined recording test pattern before recording the information.

21. (New) The optical information recording method according to claim 4, wherein a predetermined reproduction test pattern is recorded on the optical information recording medium so as to determine reproduction conditions of the information by reproducing the reproduction test pattern before reproducing the information.

22. (New) The optical information recording method according to claim 4, wherein information is further represented by the leading and trailing edges of the unit recording area.

23. (New) The optical information recording method according to claim 4, wherein power of the laser beam is lowered to a bias level in a portion between a first recording pulse for recording a first unit recording area and a second recording pulse for recording a second unit recording area when the first and second unit recording areas, each having a different mark width other than zero, are recorded continuously as the unit recording areas.

24. (New) The optical information recording method according to claim 4, further comprising selecting whether the information is represented by a width of the unit recording area in accordance with a type of information.

REMARKS

Applicants respectfully request that the preliminary amendment described herein be entered into the record prior to calculation of the filing fee and prior to examination and consideration of the above-identified application.

A new abstract page is supplied to conform to that appearing on the publication page of the WIPO application.

Claims 7-11 have been amended to remove the multiple dependencies.

If a telephone conference would be helpful in resolving any issues concerning this communication, please contact Applicants' primary attorney-of record, Douglas P. Mueller (Reg. No. 30,300), at (612) 371.5237.

Respectfully submitted,

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Dated: November 26, 2001

By ______________________
Douglas P. Mueller
Reg. No. 30,300

DPM/hb

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Narumi et al.	Docket No.:	10873.771USWO
Serial No.:	unknown	Filed:	concurrent herewith
Int'l Appln No.:	PCT/JP00/03480	Int'l Filing Date:	May 30, 2000
Title:	OPTICAL INFORMATION RECORDING METHOD......		

VERSION WITH MARKINGS TO SHOW CHANGES MADE

7. (Amended) The optical information recording method according to claim 1 ~~or 4~~, wherein amounts of correction of the leading and trailing edge positions of the recording pulse are determined by recording and reproducing a predetermined recording test pattern before recording the information.

8. (Amended) The optical information recording method according to claim 1 ~~or 4~~, wherein a predetermined reproduction test pattern is recorded on the optical information recording medium so as to determine reproduction conditions of the information by reproducing the reproduction test pattern before reproducing the information.

9. (Amended) The optical information recording method according to claim 1 ~~or 4~~, wherein information is further represented by the leading and trailing edges of the unit recording area.

10. (Amended) The optical information recording method according to claim 1 ~~or 4~~, wherein power of the laser beam is lowered to a bias level in a portion between a first recording pulse for recording a first unit recording area and a second recording pulse for recording a second unit recording area when the first and second unit recording areas, each having a different mark width other than zero, are recorded continuously as the unit recording areas.

11. (Amended) The optical information recording method according to claim 1 ~~or 4~~, further comprising selecting whether the information is represented by a width of the unit recording area in accordance with a type of information.

ABSTRACT

An edge position of a recording pulse is corrected according to multi-valued information for determining the width of a mark in an edge position correction circuit, thereby it is possible to form a mark edge in a correct position when a mark with any width is to be corrected to enable a correct multi-valued recording/reproducing.

7/PRTS

09/980109

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DESCRIPTION

OPTICAL INFORMATION RECORDING METHOD, OPTICAL INFORMATION RECORDING APPARATUS AND OPTICAL INFORMATION RECORDING MEDIUM

Technical Field

The present invention relates to a method and apparatus for recording multi-valued information on an optical information recording medium that allows information to be recorded/reproduced optically, such as an optical disk.

Background Art

In recent years, optical disks, optical cards, optical tapes, or the like have been proposed and under development as media for recording information optically. Of the above media, the optical disks have drawn attention, on which information can be recorded/reproduced with large capacity and high density.

One type of rewritable optical disks is a phase change optical disk. The phase change optical disk includes a recording film that is changed to be in the amorphous or crystalline state depending on thermal and cooling conditions by a laser beam. The amorphous and crystalline states can be reversed. The recording film has optical constants (refractive index and extinction coefficient) that differ in the amorphous and crystalline states. In the phase change optical disk, the two states are provided selectively on the recording film according to information signals so that the resultant optical change (a change in transmissivity or reflectivity) is used to record/reproduce the information signals.

To obtain the two states, information signals are recorded in the following manner. The recording film of an optical disk is irradiated with a laser beam in pulse form (with a power level of P_1) focused by an optical head. When the temperature of the recording film is raised to exceed the melting point, the molten portion is cooled rapidly with the passage of the laser beam to form an amorphous mark. The power level P_1 is called a recording power. For irradiation of the recording film with a focused laser beam (with a power level of P_2, $P_2 < P_1$) having an intensity that increases the recording film temperature to temperatures ranging from the crystallization temperature to the melting point, the irradiated portion of

the recording film is crystallized. The power level P_2 is called an erasing power.

In this manner, a recording pattern, including a mark of the amorphous area and a non-mark portion of the crystalline area (referred to as a space) that correspond to the information signals, is formed on a track of the optical disk. The information signal can be reproduced by utilizing a difference in the optical characteristics between the crystalline and amorphous areas.

Recently, a mark edge recording (also referred to as PWM recording) system is often used instead of a mark position recording (also referred to as PPM recording) system. In the mark position recording, information is represented by only the mark position itself. On the other hand, in the mark edge recording, it is represented by both the leading and trailing edges of a mark. Thus, the latter has the advantage of improving the recording linear density.

To achieve further improvement in the recording density, a multi-value recording method has been proposed, in which information of three or more values is recorded on a single mark. For example, JP 4 (1992) – 209319 A discloses a method for recording multi-valued information by forming marks having different sizes with laser beam irradiation of at least three power levels.

However, the conventional multi-value recording method described above has a problem in that, particularly when used with the mark edge recording, information cannot be reproduced accurately due to an increase in the jitter of a reproduced signal. This is because the leading and trailing edges of an area in the mark where a width of the mark is constant and a space area where the width is zero (hereinafter, each of those areas is referred to as a unit recording area) are not formed at the precise positions.

For example, when a unit recording area with a large mark width is recorded according to multi-valued information, the recording power of a laser beam is increased, causing an increase in energy applied to a recording film. Since thermal diffusion in the recording film is isotropic substantially on the disk plane, the length of the unit recording area tends to be longer than a predetermined length. On the other hand, when a unit recording area with a small mark width is recorded, the recording power of the laser beam is reduced. Therefore, the length of the unit recording area tends to be shorter than a predetermined length. As a result, the leading and

trailing edges of the unit recording area thus formed are shifted variously from the predetermined positions depending on the width thereof, which corresponds to a value of the multi-valued information. This prevents accurate reproduction of information that is represented by each edge of a unit recording area.

Disclosure of Invention

Therefore, with the foregoing in mind, it is an object of the present invention to provide a method and apparatus for recording optical information that can record multi-valued information with accuracy and high density by setting the leading and trailing edges of a recording pulse appropriately.

To achieve the above object, a first optical information recording method of the present invention includes irradiating an optical information recording medium with a laser beam to cause a change in the optical characteristics of a photosensitive recording film so that information is recorded as a mark. An area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area. Information is represented by at least three different widths (i.e., three or more widths, including zero; the same is true in the following) of the unit recording areas. The unit recording area having a predetermined length and a predetermined width is formed by correcting the leading and trailing edge positions of a recording pulse for recording the unit recording area other than the space area in accordance with a width of the unit recording area to be recorded.

This method can set both the recording power and the pulse waveform of a laser beam according to the width of a unit recording area to be recorded. Therefore, even if the unit recording area has any width, its leading and trailing edges can be formed at predetermined positions, resulting in accurate recording/reproduction of information.

In the first optical information recording method, it is preferable that the unit recording area having a predetermined length and a predetermined width is formed by correcting the leading and trailing edge positions of the recording pulse in accordance with a combination of a width and a length of the unit recording area to be recorded.

Moreover, it is preferable that the unit recording area having a predetermined length and a predetermined width is formed by correcting

the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the preceding unit recording area and by correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the next unit recording area.

These methods can set the waveform of a recording pulse according to the length of a unit recording area to be recorded as well as the lengths of the preceding and next unit recording areas, each having a different width. Therefore, the leading and trailing edges of the unit recording area can be formed more precisely at predetermined positions.

To achieve the above object, a second optical information recording method of the present invention includes irradiating an optical information recording medium with a laser beam to cause a change in the optical characteristics of a photosensitive recording film so that information is recorded as a mark. An area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area. Information is represented by at least three different widths of the unit recording areas. The unit recording area having a predetermined length and a predetermined width is formed by correcting the leading edge position of a recording pulse for recording the unit recording area other than the space area in accordance with a combination of a width of the unit recording area to be recorded and a width of the preceding unit recording area and by correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded and a width of the next unit recording area.

This method can set the edge positions of a recording pulse according to the width of a unit recording area to be recorded as well as the widths of the preceding and next unit recording areas. Therefore, even if any combination of widths is provided, the leading and trailing edges of the unit recording area can be formed at predetermined positions, resulting in more accurate recording/reproduction of information.

In the second optical information recording method, it is preferable that the unit recording area having a predetermined length and a predetermined width is formed by correcting the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area

and a length of the unit recording area to be recorded and by correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the next unit recording area and a length of the unit recording area to be recorded.

Moreover, it is preferable that the unit recording area having a predetermined length and a predetermined width is formed by correcting the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area, a length of the unit recording area to be recorded and a length of the preceding unit recording area and by correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the next unit recording area, a length of the unit recording area to be recorded and a length of the next unit recording area.

These methods can set the edge positions of a recording pulse according to the length of a unit recording area to be recorded as well as the lengths of the preceding and next unit recording areas, each having a different width. Therefore, the leading and trailing edges of the unit recording area can be formed more precisely at predetermined positions.

In the first and second optical information recording methods, it is preferable that the amounts of correction of the leading and trailing edge positions of the recording pulse are determined by recording and reproducing a predetermined recording test pattern before recording the information.

This method can determine the optimum amount of correction for an optical information recording medium to be used in recording information. Therefore, even if the optical information recording medium has recording characteristic variations, information can be recorded accurately.

In the first and second optical information recording methods, it is preferable that a predetermined reproduction test pattern is recorded on the optical information recording medium so as to determine reproduction conditions of the information by reproducing the reproduction test pattern before reproducing the information.

This method can determine the optimum reproduction conditions for an optical information recording medium to be used in recording information. Therefore, information can be reproduced accurately even if

the shapes of marks are varied due to the recording characteristic variations of the optical information recording medium.

The first and second optical information recording methods are suitable particularly for the case where information is further represented by the leading and trailing edges of the unit recording area as described above.

In the first and second optical information recording methods, it is preferable that the power of the laser beam is lowered to a bias level in the portion between a first recording pulse for recording a first unit recording area and a second recording pulse for recording a second unit recording area when the first and second unit recording areas, each having a different mark width other than zero, are recorded continuously as the unit recording areas.

Conventionally, the power level of a laser beam is changed simply according to the width of a mark to be formed without lowering to a bias level. The above method is one aspect of the present invention, in which a pulse is separated by temporarily lowering the level so that the edge positions are corrected precisely.

It is preferable that the first and second optical information recording methods further include selecting whether the information is represented by a width of the unit recording area in accordance with the type of information.

This method allows information to be represented by only edge positions or the like instead of a mark width, e.g., when the information to be recorded requires particularly low error rate. Therefore, the method can select recording with high recording density or low error rate according to information to be recorded, thus providing optimum recording based on the information.

The present invention also provides an optical information recording medium suitable for recording information with the above optical information recording methods.

A first optical information recording medium of the present invention includes a photosensitive recording film whose optical characteristics are changed by laser beam irradiation. An area where a width of a mark that is formed on the photosensitive recording film by the laser beam irradiation is constant and a space area where the width is zero each are defined as a unit recording area. An identifier for identifying

whether information is represented by a width of the unit recording area is recorded previously on a predetermined area.

A recording/reproducing apparatus that uses this medium can recognize easily whether information recorded on the medium is represented by the width of a unit recording area by reproducing the identifier.

A second optical information recording medium of the present invention includes a photosensitive recording film whose optical characteristics are changed by laser beam irradiation. An area where a width of a mark that is formed on the photosensitive recording film by the laser beam irradiation is constant and a space area where the width is zero each are defined as a unit recording area. The amounts of correction of the leading and trailing edge positions of a recording pulse for recording the unit recording area other than the space area that are determined by a width of the unit recording area to be recorded are recorded previously on a predetermined area as information.

The use of this medium enables recording with the optimum amount of correction that has been recorded thereon. Thus, even if the optical information recording medium has recording characteristic variations, information can be recorded accurately without determining the amount of correction by recording/reproducing a test pattern.

To achieve the above object, a first optical information recording apparatus of the present invention is an apparatus for recording information on an optical information recording medium. The optical information recording medium is irradiated with a laser beam having a plurality of powers while switching the power of the laser beam to cause a change in the optical characteristics of a photosensitive recording film so that a mark is formed. An area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area, and information is represented by at least three different widths of the unit recording areas. The apparatus includes a modulation means for modulating recording information to provide modulated information, a multi-valued means for converting the modulated information to multi-valued information, a recording pulse generation means for generating a recording pulse based on the multi-valued information, a recording power control means for controlling a recording power in accordance with a width of the unit recording area to be recorded

that corresponds to the multi-valued information, an edge position correction means for correcting leading and trailing edge positions of the recording pulse in accordance with the width of the unit recording area to be recorded, and a recording means for recording the information on the optical information recording medium by irradiation of the laser beam based on the recording power and the corrected recording pulse.

This apparatus can set both the recording power and the pulse waveform of a laser beam according to the width of a unit recording area to be recorded. Therefore, even if the unit recording area has any width, its leading and trailing edges can be formed at predetermined positions, resulting in accurate recording/reproduction of information.

In the first optical information recording apparatus, it is preferable that the edge position correction means corrects the leading and trailing edge positions of the recording pulse in accordance with a combination of a width and a length of the unit recording area to be recorded.

Moreover, it is preferable that the edge position correction means corrects the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the preceding unit recording area and the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the next unit recording area.

These apparatuses can set the waveform of a recording pulse according to the length of a unit recording area to be recorded as well as the lengths of the preceding and next unit recording areas, each having a different width. Therefore, the leading and trailing edges of the unit recording area can be formed more precisely at predetermined positions.

To achieve the above object, a second optical information recording apparatus of the present invention is an apparatus for recording information on an optical information recording medium. The optical information recording medium is irradiates with a laser beam having a plurality of powers while switching the power of the laser beam to cause a change in the optical characteristics of a photosensitive recording film so that a mark is formed. An area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area, and information is represented by at least three different widths of the unit recording areas. The apparatus includes a modulation

means for modulating recording information to provide modulated information, a multi-valued means for converting the modulated information to multi-valued information, a recording pulse generation means for generating a recording pulse based on the multi-valued information, a recording power control means for controlling a recording power in accordance with a width of the unit recording area to be recorded that corresponds to the multi-valued information, an edge position correction means for correcting the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded and a width of the preceding unit recording area and for correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded and a width of the next unit recording area, and a recording means for recording the information on the optical information recording medium by irradiation of the laser beam based on the recording power and the corrected recording pulse.

This apparatus can set both the recording power and the pulse waveform of a laser beam according to the width of a unit recording area to be recorded as well as the widths of the preceding and next unit recording areas. Therefore, even if the unit recording area has any width, its leading and trailing edges can be formed at predetermined positions, resulting in accurate recording/reproduction of information.

In the second optical information recording apparatus, it is preferable that the edge position correction means corrects the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area and a length of the unit recording area to be recorded, and the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the next unit recording area and a length of the unit recording area to be recorded.

Moreover, it is preferable that the edge position correction means corrects the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area, a length of the unit recording area to be recorded and a length of the preceding unit recording area, and the trailing edge position of the recording pulse in accordance with a combination of a

width of the recording unit area to be recorded, a width of the next unit recording area, a length of the unit recording area to be recorded and a length of the next unit recording area.

These apparatuses can set the edge positions of a recording pulse according to the length of a unit recording area to be recorded as well as the lengths of the preceding and next unit recording areas, each having a different width. Therefore, the leading and trailing edges of the unit recording area can be formed more precisely at predetermined positions.

<u>Brief Description of Drawings</u>

FIG. 1 is a block diagram showing the configuration of an embodiment of a recording apparatus of the present invention.

FIGS. 2(a) to 2(e) are signal waveform diagrams and a track state diagram that illustrate a recording operation of an embodiment of a recording method of the present invention:

FIG. 2(a) illustrates four-valued information;

FIG. 2(b) is a waveform diagram of a recording pulse;

FIG. 2(c) is a waveform diagram of a corrected recording pulse to be input to a laser driving circuit;

FIG. 2(d) is a waveform diagram illustrating a change in the emission power of a laser beam; and

FIG. 2(e) illustrates the recorded state of marks on a track.

FIGS. 3(a) to 3(d) are a track state diagram and signal waveform diagrams that illustrate an example of operation for reproducing information recorded according to the present invention:

FIG. 3(a) illustrates the recorded state of marks on a track;

FIG. 3(b) is a waveform diagram of a reproduced signal;

FIG. 3(c) is a waveform diagram of a four-valued signal; and

FIG. 3(d) shows four-valued information.

FIGS. 4(a) to 4(d) are signal waveform diagrams and a track state diagram that illustrate a conventional recording method:

FIG. 4(a) illustrates four-valued information;

FIG. 4(b) is a waveform diagram of a recording pulse;

FIG. 4(c) is a waveform diagram of a recording pulse to be input to a laser driving circuit;

FIG. 4(d) is a waveform diagram illustrating a change in the emission power of a laser beam; and

FIG. 4(e) illustrates the recorded state of marks on a track.

FIGS. 5(a) to 5(e) are signal waveform diagrams and a track state diagram that illustrate a recording operation of another embodiment of a recording method of the present invention:

FIG. 5(a) illustrates four-valued information;

FIG. 5(b) is a waveform diagram of a recording pulse;

FIG. 5(c) is a waveform diagram of a corrected recording pulse to be input to a laser driving circuit;

FIG. 5(d) is a waveform diagram illustrating a change in the emission power of a laser beam; and

FIG. 5(e) illustrates the recorded state of marks on a track.

FIGS. 6(a) to 6(e) are signal waveform diagrams and a track state diagram that illustrate a recording operation of yet another embodiment of a recording method of the present invention:

FIG. 6(a) illustrates four-valued information;

FIG. 6(b) is a waveform diagram of a recording pulse;

FIG. 6(c) is a waveform diagram of a corrected recording pulse to be input to a laser driving circuit;

FIG. 6(d) is a waveform diagram illustrating a change in the emission power of a laser beam; and

FIG. 6(e) illustrates the recorded state of marks on a track.

FIG. 7 shows the relationship between the recording power and the reproduced signal amplitude of an optical disk.

Detailed Description of the Invention

Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings.

FIG. 1 is a block diagram showing the schematic configuration of a recording/reproducing apparatus (optical information recording apparatus) of an embodiment of the present invention.

The recording/reproducing apparatus of this embodiment uses an optical disk 1 to record/reproduce information. Examples of the optical disk 1 include a phase change optical disk, a magneto-optical disk, and a disk employing dye as a recording layer. Alternatively, the master of a stamper with a photoresist coating for producing a read-only disk may be used.

The recording/reproducing apparatus includes a spindle motor 2 and an optical head 10: the spindle motor 2 rotates the optical disk 1; the optical

head 10 includes a laser source (not shown) and focuses a laser beam on the desired portion of the optical disk 1. The whole operation of the recording/reproducing apparatus is controlled by a system control circuit 3.

The recording/reproducing apparatus includes a modulation circuit 4, a multi-valued circuit 5, a recording pulse generation circuit 6, and an edge position correction circuit 7 as a recording means. The modulation circuit 4 modulates recording information according to a predetermined modulation rule to provide modulated information. The multi-valued circuit 5 generates multi-valued information according to the modulated information. The recording pulse generation circuit 6 generates a recording pulse according to the multi-valued information. The edge position correction circuit 7 corrects the edge positions of the recording pulse. The recording/reproducing apparatus further includes a power control circuit 9 that sets the power of the laser beam based on the multi-valued information. Moreover, it is provided with a laser driving circuit 8 that modulates the current for driving the laser source in the optical head 10 according to a recording pulse output from the edge position correction circuit 7 and a control signal from the power control circuit 9.

The recording/reproducing apparatus includes a reproduced signal processing circuit 11, a multi-valued information generation circuit 12, and a demodulation circuit 13 as a reproduction means for reproducing information from the optical disk 1. The reproduced signal processing circuit 11 performs waveform processing (such as equalizing) of a reproduced signal based on the reflected light from the optical disk 1. The multi-valued information generation circuit 12 generates four-valued information from the reproduced signal. The demodulation circuit 13 demodulates reproduced information from the multi-valued information.

Next, the operation of the recording/reproducing apparatus of this embodiment will be described with reference to signal waveform diagrams and track state diagrams in FIGS. 2 and 3. FIG. 2 corresponds to the operation for recording four-valued information, and FIG. 3 corresponds to the operation for reproducing four-valued information.

For recording, first, the system control circuit 3 rotates the spindle motor 2 so that the optical head 10 seeks a predetermined track on the optical disk 1, and thus the system control circuit 3 determines a set value of recording power in the power control circuit 9. Then, the system control circuit 3 generates recording information based on data from a host

processor and sends it to the modulation circuit 4. The modulation circuit 4 transmits modulated information to the multi-valued circuit 5. The multi-valued circuit 5 outputs four-valued information as shown in FIG. 2(a) to each of the recording pulse generation circuit 6, the edge position correction circuit 7, and the power control circuit 9.

The recording pulse generation circuit 6 generates a recording pulse as shown in FIG. 2(b) based on the four-valued information. The recording pulse may be produced with two-bit signals (i.e., two binary information signals).

The recording pulse generation circuit 6 transmits the recording pulse to the edge position correction circuit 7. According to the four-valued information from the multi-valued circuit 5, the edge position correction circuit 7 corrects the waveform of the recording pulse transmitted from the recording pulse generation circuit as shown in FIG. 2(c). The amount of correction (Δ_{1F}, Δ_{1L}, Δ_{2F}, Δ_{2L}, Δ_{3F}, Δ_{3L}) is registered on a memory within the edge position correction circuit 7 as information shown in Tables 1 and 2. The recording pulse waveform is corrected by referring to the memory. For example, when the four-valued information is "3", the leading edge of the recording pulse is delayed by Δ_{3F} and the trailing edge is advanced by Δ_{3L}. When the four-valued information is "2" or "1", both edges are corrected in the same manner, respectively. When the four-valued information is "0", it corresponds to a space (i.e., a non-mark portion) in this embodiment, where no recording pulse is present that requires edge correction. Therefore, the recording pulse is not corrected.

TABLE 1

Four-valued information	Amount of correction of a leading edge
"0"	-
"1"	Δ_{1F}
"2"	Δ_{2F}
"3"	Δ_{3F}

TABLE 2

Four-valued information	Amount of correction of a trailing edge
"0"	-
"1"	Δ_{1L}
"2"	Δ_{2L}
"3"	Δ_{3L}

The power control circuit 9 determines a recording power of a laser beam based on the four-valued information. In this embodiment, the four-valued information is related to the recording power, as shown in Table 3.

For example, when information is recorded on a phase change optical disk with the same recording pulse width, the relationship between the recording power and the reproduced signal amplitude is such as to be shown in FIG. 7, and the width of a mark is increased with increasing reproduced signal amplitude. Therefore, the recording powers P_{p1}, P_{p2}, and P_{p3} can be selected so as to differ in reproduced signal amplitude, as indicated by the three points of A_1, A_2, and A_3 in FIG. 7.

The laser driving circuit modulates the current for driving the laser based on a control signal from the power control circuit 9 and the recording pulse whose edge positions have been corrected. Consequently, the laser beam emitted has a waveform as shown in FIG. 2(d).

TABLE 3

Four-valued information	Recording power
"0"	-
"1"	P_{p1}
"2"	P_{p2}
"3"	P_{p3}

The optical head 10 performs a recording operation on a predetermined track. Thus, as shown in FIG. 2(e), recording marks 202, 203 and unit recording areas 204, 205, 206, and 207, each having a predetermined length based on the four-valued information, are formed on a track 201. Since the width of a unit recording area is determined by a recording power, each of the unit recording areas has a predetermined width based on the four-valued information (i.e., the mark areas with widths of W_1, W_2, and W_3 and the space area with zero width).

For reproduction, the track 201, on which the unit recording areas 204, 205, 206, and 207 are formed as shown in FIG. 3(a), is irradiated with reproduction power by the laser in the optical head 10. Then, a photodetector in the optical head 10 receives the reflected light and converts it to an electric signal. FIG. 3(b) shows the waveform of the reproduced signal thus converted, indicating that the signal of levels corresponding to the widths of the unit recording areas is reproduced. The reproduced signal processing circuit 11 equalizes the reproduced signal waveform and slices the signal levels, so that the reproduced signal is converted to a four-valued signal (see FIG. 3(c)). This embodiment employs three slice levels (i.e., S_1, S_2, and S_3 in FIG. 3(b)) to detect the levels of four values. The multi-valued information generation circuit 12 generates four-valued information as shown in FIG. 3(d), and the demodulation circuit 13 demodulates reproduced information.

As described above, the reason why the leading and trailing edges of a recording pulse are corrected according to the width of a unit recording area to be recorded is that the length of the unit recording area is shifted variously from a predetermined length to be recorded when the unit recording areas with different widths are recorded.

Generally, a higher recording power is necessary to record the unit recording area having a large width. Increased recording power causes an increase in energy to be applied to the recording film. Therefore, the length of the unit recording area tends to be longer than a predetermined length. This phenomenon will be described below by illustrating a conventional example.

FIGS. 4(a) to 4(e) show signal waveforms and the state of marks recorded on a track in a conventional multi-value recording method and correspond to FIGS. 2(a) to 2(e) of this embodiment, respectively.

In the conventional multi-value recording method, when four-valued information as shown in FIG. 4(a) is recorded, a recording pulse (FIG. 4(b)) is not corrected by the four-valued information. Therefore, the laser beam emitted has a waveform as shown in FIG. 4(d) and produces a recording power P_{p3} for the four-valued information of "3", resulting in large energy application to the recording film of an optical disk. Thus, the length of each recording mark 401, 402 becomes longer than a predetermined length, as shown in FIG. 4(e). Specifically, elongations 407 and 408 appear at the leading edge of a unit recording area 403 and the trailing edge of a unit

recording area 404, respectively; also, elongations 409 and 410 appear at both edges of a unit recording area 406 that is separated by a unit recording area (space area) 405.

Similarly, the leading and trailing edges elongate when the four-valued information is "2". However, since the recording power P_{p2} is lower than P_{p3}, the tendency to elongation is reduced, compared with the four-valued information of "3". When the four-valued information is "1", the leading and trailing edges elongate as well. However, the tendency is smaller than that for the four-valued information of "2" for the same reason.

As described above, the tendency of a unit recording area to elongate differs depending on four-valued information (i.e., the width of a unit recording area to be recorded). This leads to the deviation of a reproduced signal from a predetermined timing during reproduction, which in turn causes various timing deviations of the four-valued signal that is converted from the reproduced signal. Consequently, jitter is increased, making accurate reproduction of information impossible.

On the other hand, this embodiment corrects the leading and trailing edges of a recording pulse so that the unit recording having a predetermined length can be recorded. The amount of correction of each edge is set so as to record the unit recording area with a predetermined length. Since high power recording generally tends to increase the length of a unit recording area, the amount of correction of a recording pulse for high power recording is larger than that for low power recording.

As described above, this embodiment corrects the leading and trailing edges of a recording pulse according to the width of a unit recording area to be recorded (i.e., four-valued information). Thus, even if the unit recording area has any width, its edges can be formed at the precise positions. Therefore, this embodiment has a special effect of recording and reproducing multi-valued information accurately.

Also, this embodiment performs the above correction in the following manner: when the unit recording areas 204 and 205, each having a different mark width other than zero, are recorded continuously as shown in FIG. 2, the power of a laser beam is lowered to a bias level of P_b in the portion between a recording pulse for recording the unit recording area 204 and that for the unit recording area 205.

In this embodiment, the waveform of a recording pulse is corrected according to the width of a unit recording area to be recorded. It is

preferred to correct the recording pulse waveform as follows.

The first method is such that the recording pulse waveform is corrected according to the length of a unit recording area to be recorded, in addition to the width thereof. Generally, the length of a unit recording area tends to be longer than a predetermined length because the amount of heat accumulated increases with irradiation time even under the same recording power. Thus, the correction according to not only the width but also the length of a unit recording area enables more precise formation of the edges.

The second method is such that the leading and trailing edge positions of a recording pulse are corrected respectively by combining the width of a unit recording area to be recorded with both a width of the preceding unit recording area and a width of the next unit recording area. Considering the mutual influence of the adjacent unit recording areas enables more precise formation of the edges. Here, the second method will be described.

The amount of correction in this case is registered on a memory within the edge position correction circuit 7 in FIG. 1 as information shown in Tables 4 and 5. The leading and trailing edges of a recording pulse are corrected by referring to the memory. The same correction is made when the second information has different combinations. FIGS. 5(a) to 5(e) show signal waveforms and the state of marks recorded on a track in a multi-value recording method of this embodiment and correspond to FIGS. 2(a) to 2(e), respectively. In FIG. 5, e.g., when four-valued information to be recorded is "3" and the preceding information is "0", the leading edge of a recording pulse is delayed by Δ_{03F}. When the four-valued information to be recorded is "3" and the next information is "2", the trailing edge is advanced by Δ_{32L}.

In this manner, recording marks 501 and 502, each having a predetermined length, are formed on a track 201, which enables precise formation of unit recording areas 503 (with a width of W_3), 504 (with a width of W_2), 505 (with zero width) and 506 (with a width of W_1).

TABLE 4

Amount of correction of a leading edge					
		Four-valued information			
		"0"	"1"	"2"	"3"
The preceding four-valued information	"0"	-	Δ_{01F}	Δ_{02F}	Δ_{03F}
	"1"	-	Δ_{11F}	Δ_{12F}	Δ_{13F}
	"2"	-	Δ_{21F}	Δ_{22F}	Δ_{23F}
	"3"	-	Δ_{31F}	Δ_{32F}	Δ_{33F}

TABLE 5

Amount of correction of a trailing edge					
		Four-valued information			
		"0"	"1"	"2"	"3"
The next four-valued information	"0"	-	Δ_{10L}	Δ_{20L}	Δ_{30L}
	"1"	-	Δ_{11L}	Δ_{21L}	Δ_{31L}
	"2"	-	Δ_{12L}	Δ_{22L}	Δ_{32L}
	"3"	-	Δ_{13L}	Δ_{23L}	Δ_{33L}

The above operation can correct the variation in thermal interference resulting from various differences in widths of the preceding and next unit recording areas. Therefore, the unit recording area can be recorded at more precise edge positions. In this case, the amount of correction is increased with increasing width of a unit recording area to be recorded (e.g., $\Delta_{01F} < \Delta_{02F} < \Delta_{03F}$ holds in the first row of Table 4).

Moreover, it is preferred to use the above method with the following method: the leading and trailing edges of a recording pulse are corrected according to the length of a unit recording area as well as the lengths of the preceding and next unit recording areas. The amount of correction in this case is registered on a memory within the edge position correction circuit 7 in FIG. 1 as information shown in Tables 6 and 7. The leading and trailing edges of a recording pulse are corrected by referring to the memory. The same correction is made when the second information has different combinations. Tables 6 and 7 show a modulation system in which the length of a unit recording area can range from 2T to 7T (T indicates a clock cycle).

TABLE 6

<table>
<tr><td colspan="15">Amount of correction of a leading edge</td></tr>
<tr><td colspan="2" rowspan="2"></td><td colspan="13">Length of a unit recording area</td></tr>
<tr><td colspan="6">2T</td><td colspan="6">3T</td><td>…</td></tr>
<tr><td rowspan="19">Length of the preceding unit recording area</td><td rowspan="6">2T</td><td colspan="2" rowspan="2"></td><td colspan="4">Four-valued information</td><td colspan="2" rowspan="2"></td><td colspan="4">Four-valued information</td><td>…</td></tr>
<tr><td>"0"</td><td>"1"</td><td>"2"</td><td>"3"</td><td>"0"</td><td>"1"</td><td>"2"</td><td>"3"</td><td></td></tr>
<tr><td rowspan="4">The preceding four-valued information</td><td>"0"</td><td>–</td><td>Δ_{2201F}</td><td>Δ_{2202F}</td><td>Δ_{2203F}</td><td rowspan="4">The preceding four-valued information</td><td>"0"</td><td>–</td><td>Δ_{2301F}</td><td>Δ_{2302F}</td><td>Δ_{2303F}</td><td rowspan="4">…</td></tr>
<tr><td>"1"</td><td>–</td><td>Δ_{2211F}</td><td>Δ_{2212F}</td><td>Δ_{2213F}</td><td>"1"</td><td>–</td><td>Δ_{2311F}</td><td>Δ_{2312F}</td><td>Δ_{2313F}</td></tr>
<tr><td>"2"</td><td>–</td><td>Δ_{2221F}</td><td>Δ_{2222F}</td><td>Δ_{2223F}</td><td>"2"</td><td>–</td><td>Δ_{2321F}</td><td>Δ_{2322F}</td><td>Δ_{2323F}</td></tr>
<tr><td>"3"</td><td>–</td><td>Δ_{2231F}</td><td>Δ_{2232F}</td><td>Δ_{2233F}</td><td>"3"</td><td>–</td><td>Δ_{2331F}</td><td>Δ_{2332F}</td><td>Δ_{2333F}</td></tr>
<tr><td rowspan="6">3T</td><td colspan="2" rowspan="2"></td><td colspan="4">Four-valued information</td><td colspan="2" rowspan="2"></td><td colspan="4">Four-valued information</td><td>…</td></tr>
<tr><td>"0"</td><td>"1"</td><td>"2"</td><td>"3"</td><td>"0"</td><td>"1"</td><td>"2"</td><td>"3"</td><td></td></tr>
<tr><td rowspan="4">The preceding four-valued information</td><td>"0"</td><td>–</td><td>Δ_{3201F}</td><td>Δ_{3202F}</td><td>Δ_{3203F}</td><td rowspan="4">The preceding four-valued information</td><td>"0"</td><td>–</td><td>Δ_{3301F}</td><td>Δ_{3302F}</td><td>Δ_{3303F}</td><td rowspan="4">…</td></tr>
<tr><td>"1"</td><td>–</td><td>Δ_{3211F}</td><td>Δ_{3212F}</td><td>Δ_{3213F}</td><td>"1"</td><td>–</td><td>Δ_{3311F}</td><td>Δ_{3312F}</td><td>Δ_{3313F}</td></tr>
<tr><td>"2"</td><td>–</td><td>Δ_{3221F}</td><td>Δ_{3222F}</td><td>Δ_{3223F}</td><td>"2"</td><td>–</td><td>Δ_{3321F}</td><td>Δ_{3322F}</td><td>Δ_{3323F}</td></tr>
<tr><td>"3"</td><td>–</td><td>Δ_{3231F}</td><td>Δ_{3232F}</td><td>Δ_{3233F}</td><td>"3"</td><td>–</td><td>Δ_{3331F}</td><td>Δ_{3332F}</td><td>Δ_{3333F}</td></tr>
<tr><td>…</td><td></td><td>…</td><td colspan="4">…</td><td></td><td>…</td><td colspan="4">…</td><td>…</td></tr>
<tr><td rowspan="6">7T</td><td colspan="2" rowspan="2"></td><td colspan="4">Four-valued information</td><td colspan="2" rowspan="2"></td><td colspan="4">Four-valued information</td><td>…</td></tr>
<tr><td>"0"</td><td>"1"</td><td>"2"</td><td>"3"</td><td>"0"</td><td>"1"</td><td>"2"</td><td>"3"</td><td></td></tr>
<tr><td rowspan="4">The preceding four-valued information</td><td>"0"</td><td>–</td><td>Δ_{7201F}</td><td>Δ_{7202F}</td><td>Δ_{7203F}</td><td rowspan="4">The preceding four-valued information</td><td>"0"</td><td>–</td><td>Δ_{7301F}</td><td>Δ_{7302F}</td><td>Δ_{7303F}</td><td rowspan="4">…</td></tr>
<tr><td>"1"</td><td>–</td><td>Δ_{7211F}</td><td>Δ_{7212F}</td><td>Δ_{7213F}</td><td>"1"</td><td>–</td><td>Δ_{7311F}</td><td>Δ_{7312F}</td><td>Δ_{7313F}</td></tr>
<tr><td>"2"</td><td>–</td><td>Δ_{7221F}</td><td>Δ_{7222F}</td><td>Δ_{7223F}</td><td>"2"</td><td>–</td><td>Δ_{7321F}</td><td>Δ_{7322F}</td><td>Δ_{7323F}</td></tr>
<tr><td>"3"</td><td>–</td><td>Δ_{7231F}</td><td>Δ_{7232F}</td><td>Δ_{7233F}</td><td>"3"</td><td>–</td><td>Δ_{7331F}</td><td>Δ_{7332F}</td><td>Δ_{7333F}</td></tr>
</table>

TABLE 6 (continued)

Amount of correction of a leading edge								
		Length of a unit recording area						
		...	7T					
Length of the preceding unit recording area	2T	...			Four-valued information			
					"0"	"1"	"2"	"3"
		...	The preceding four-valued information	"0"	–	Δ2701F	Δ2702F	Δ2703F
				"1"	–	Δ2711F	Δ2712F	Δ2713F
				"2"	–	Δ2721F	Δ2722F	Δ2723F
				"3"	–	Δ2731F	Δ2732F	Δ2733F
	3T	...			Four-valued information			
					"0"	"1"	"2"	"3"
		...	The preceding four-valued information	"0"	–	Δ3701F	Δ3702F	Δ3703F
				"1"	–	Δ3711F	Δ3712F	Δ3713F
				"2"	–	Δ3721F	Δ3722F	Δ3723F
				"3"	–	Δ3731F	Δ3732F	Δ3733F
	...	...		...	...			
	7T	...			Four-valued information			
					"0"	"1"	"2"	"3"
		...	The preceding four-valued information	"0"	–	Δ7701F	Δ7702F	Δ7703F
				"1"	–	Δ7711F	Δ7712F	Δ7713F
				"2"	–	Δ7721F	Δ7722F	Δ7723F
				"3"	–	Δ7731F	Δ7732F	Δ7733F

TABLE 7

Amount of correction of a trailing edge												
				Length of a unit recording area								
				2T				3T				…
Length of the next unit recording area	2T			Four-valued information				Four-valued information				…
				"0"	"1"	"2"	"3"	"0"	"1"	"2"	"3"	
		The next four-valued information	"0"	–	Δ2210L	Δ2220L	Δ2230L	–	Δ3210L	Δ3220L	Δ3230L	…
			"1"	–	Δ2211L	Δ2221L	Δ2231L	–	Δ3211L	Δ3221L	Δ3231L	
			"2"	–	Δ2212L	Δ2222L	Δ2232L,	–	Δ3212L	Δ3222L	Δ3232L	
			"3"	–	Δ2213L	Δ2223L	Δ2233L	–	Δ3213L	Δ3223L	Δ3233L	
	3T			Four-valued information				Four-valued information				…
				"0"	"1"	"2"	"3"	"0"	"1"	"2"	"3"	
		The next four-valued information	"0"	–	Δ2310L	Δ2320L	Δ2330L	–	Δ3310L	Δ3320L	Δ3330L	…
			"1"	–	Δ2311L	Δ2321L	Δ2331L	–	Δ3311L	Δ3321L	Δ3331L	
			"2"	–	Δ2312L	Δ2322L	Δ2332L	–	Δ3312L	Δ3322L	Δ3332L	
			"3"	–	Δ2313L	Δ2323L	Δ2333L	–	Δ3313L	Δ3323L	Δ3333L	
	…		…	…				…	…			…
	7T			Four-valued information				Four-valued information				…
				"0"	"1"	"2"	"3"	"0"	"1"	"2"	"3"	
		The next four-valued information	"0"	–	Δ2710L	Δ2720L	Δ2730L	–	Δ3710L	Δ3720L	Δ3730L	…
			"1"	–	Δ2711L	Δ2721L	Δ2731L	–	Δ3711L	Δ3721L	Δ3731L	
			"2"	–	Δ2712L	Δ2722L	Δ2732L	–	Δ3712L	Δ3722L	Δ3732L	
			"3"	–	Δ2713L	Δ2723L	Δ2733L	–	Δ3713L	Δ3723L	Δ3733L	

TABLE 7 (continued)

Amount of correction of a trailing edge								
		Length of a unit recording area						
		…	7T					
Length of the next unit recording area	2T	…			Four-valued information			
					"0"	"1"	"2"	"3"
		…	The next four-valued information	"0"	–	Δ7210L	Δ7220L	Δ7230L
				"1"	–	Δ7211L	Δ7221L	Δ7231L
				"2"	–	Δ7212L	Δ7222L	Δ7232L
				"3"	–	Δ7213L	Δ7223L	Δ7233L
	3T	…			Four-valued information			
					"0"	"1"	"2"	"3"
		…	The next four-valued information	"0"	–	Δ7310L	Δ7320L	Δ7330L
				"1"	–	Δ7311L	Δ7321L	Δ7331L
				"2"	–	Δ7312L	Δ7322L	Δ7332L
				"3"	–	Δ7313L	Δ7323L	Δ7333L
	…	…		…	…			
	7T	…			Four-valued information			
					"0"	"1"	"2"	"3"
		…	The next four-valued information	"0"	–	Δ7710L	Δ7720L	Δ7730L
				"1"	–	Δ7711L	Δ7721L	Δ7731L
				"2"	–	Δ7712L	Δ7722L	Δ7732L
				"3"	–	Δ7713L	Δ7723L	Δ7733L

FIGS. 6(a) to 6(e) show signal waveforms and the state of marks recorded on a track in a multi-value recording method of this embodiment and correspond to FIG. 2(a) to 2(e), respectively. In FIG. 6, e.g., when four-valued information to be recorded is "3", the preceding information is "0", the length of a unit recording area to be recorded is 3T and the length of the preceding unit recording area is 5T, the leading edge of a recording pulse is delayed by Δ_{5303F}. When the four-valued information to be recorded is "3", the next information is "2", the length of the unit recording area to be recorded is 3T and the length of the next unit recording area is 2T, the trailing edge is advanced by Δ_{3232L}.

The above operation can correct the variation in thermal interference resulting from various differences in lengths of a unit recording area itself and the preceding and next unit recording areas. Therefore, marks can be recorded at more precise edge positions.

The embodiment shown in FIG. 6 also allows recording marks 601 and 602, each having a predetermined length, to be formed on a track 201, which enables precise formation of unit recording areas 603 (with a width of W_3), 604 (with a width of W_2), 605 (with zero width) and 606 (with a width of W_1).

In an optical information recording method of this embodiment, it is preferable that prior to recording information, the amount of correction of the leading and trailing edge positions of a recording pulse is determined by recording and reproducing a predetermined recording test pattern. This method can determine the optimum amount of correction for an optical information recording medium to be used in recording information. Therefore, even if the optical information recording medium has recording characteristic variations, information can be recorded accurately.

In an optical information recording method of this embodiment, it is preferable that prior to reproducing information, reproduction conditions for the information are determined by reproducing a predetermined reproduction test pattern recorded on the optical information recording medium. This method can determine the optimum reproduction conditions (such as equalizer characteristics) for an optical information recording medium to be used in recording information. Therefore, information can be reproduced accurately even if the shapes of marks are varied due to the recording characteristic variations of the optical information recording medium.

It is preferable that an optical information recording method of this embodiment includes a process for selecting whether information is represented by the width of a unit recording area according to the type of information. This method allows information to be represented by only mark edge positions when the information to be recorded requires a particularly low error rate. Therefore, the method can select recording with high recording density or low error rate according to the information to be recorded, thus providing optimum recording based on the information.

For an optical information recording medium on which information is recorded with an optical information recording method of this embodiment, it is preferable that an identifier for identifying whether information is represented by the width of a unit recording area is recorded on a predetermined area of the medium. A recording/reproducing apparatus that uses this medium can recognize easily whether information recorded on the medium is represented by the width of a unit recording area by reproducing the identifier.

For an optical information recording medium on which information is recorded with an optical information recording method of this embodiment, it is preferable that the amount of correction of the leading and trailing edge positions of a recording pulse is recorded previously on a predetermined area of the medium as information. The use of this medium enables recording with the optimum amount of correction that has been recorded thereon. Thus, even if the optical information recording medium has recording characteristic variations, information can be recorded accurately without determining the amount of correction by recording/reproducing a test pattern.

A material for the optical disk is not limited to that described above, and the above method can be applied to any media, as long as they have optical characteristics that differ in the recording mark and non-mark portions, such as made of a magneto-optical material, dye material, or the like. The number of values that information has after conversion, the above recording power, modulation system, length and position of each pulse, or the like are not limited to those mentioned in the present embodiments; it should be noted that the invention can set these elements appropriately according to recording conditions or media. For example, in the above embodiments, each of the unit recording areas is recorded with a single recording pulse. However, the recording pulse may be composed of a

multipulse.

Industrial Applicability

As described above, the present invention selects at least one appropriate factor from the widths and lengths of a unit recording area to be recorded and the preceding and next unit recording areas, and corrects the leading and/or trailing edge positions of a recording pulse according to the factor (when a plurality of factors are selected, a combination of those factors is used). The present invention can provide a special effect of recording and reproducing multi-valued information accurately with the position correction. In view of such effect, it is obvious that the present invention is very useful in the field of optical information recording.

CLAIMS

1. An optical information recording method, comprising irradiating an optical information recording medium with a laser beam to cause a change in optical characteristics of a photosensitive recording film so that information is recorded as a mark,

wherein an area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area,

information is represented by at least three different widths of the unit recording areas, and

the unit recording area having a predetermined length and a predetermined width is formed by correcting leading and trailing edge positions of a recording pulse for recording the unit recording area other than the space area in accordance with a width of the unit recording area to be recorded.

2. The optical information recording method according to claim 1, wherein the unit recording area having a predetermined length and a predetermined width is formed by correcting the leading and trailing edge positions of the recording pulse in accordance with a combination of a width and a length of the unit recording area to be recorded.

3. The optical information recording method according to claim 2, wherein the unit recording area having a predetermined length and a predetermined width is formed by correcting the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the preceding unit recording area and by correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the next unit recording area.

4. An optical information recording method, comprising irradiating an optical information recording medium with a laser beam to cause a change in optical characteristics of a photosensitive recording film so that information is recorded as a mark,

wherein an area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area,

information is represented by at least three different widths of the unit recording areas, and

the unit recording area having a predetermined length and a predetermined width is formed by correcting a leading edge position of a recording pulse for recording the unit recording area other than the space area in accordance with a combination of a width of the unit recording area to be recorded and a width of the preceding unit recording area and by correcting a trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded and a width of the next unit recording area.

5. The optical information recording method according to claim 4, wherein the unit recording area having a predetermined length and a predetermined width is formed by correcting the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area and a length of the unit recording area to be recorded and by correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the next unit recording area and a length of the unit recording area to be recorded.

6. The optical information recording method according to claim 5, wherein the unit recording area having a predetermined length and a predetermined width is formed by correcting the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area, a length of the unit recording area to be recorded and a length of the preceding unit recording area and by correcting the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the next unit recording area, a length of the unit recording area to be recorded and a length of the next unit recording area.

7. The optical information recording method according to claim 1 or 4, wherein amounts of correction of the leading and trailing edge positions of the recording pulse are determined by recording and reproducing a predetermined recording test pattern before recording the information.

8. The optical information recording method according to claim 1 or 4, wherein a predetermined reproduction test pattern is recorded on the optical information recording medium so as to determine reproduction conditions of the information by reproducing the reproduction test pattern before reproducing the information.

9. The optical information recording method according to claim 1 or 4, wherein information is further represented by the leading and trailing edges of the unit recording area.

10. The optical information recording method according to claim 1 or 4, wherein power of the laser beam is lowered to a bias level in a portion between a first recording pulse for recording a first unit recording area and a second recording pulse for recording a second unit recording area when the first and second unit recording areas, each having a different mark width other than zero, are recorded continuously as the unit recording areas.

11. The optical information recording method according to claim 1 or 4, further comprising selecting whether the information is represented by a width of the unit recording area in accordance with a type of information.

12. An optical information recording medium, comprisinga photosensitive recording film whose optical characteristics are changed by laser beam irradiation,

wherein an area where a width of a mark that is formed on the photosensitive recording film by the laser beam irradiation is constant and a space area where the width is zero each are defined as a unit recording area, and

an identifier for identifying whether information is represented by a width of the unit recording area is recorded previously on a predetermined area.

13. An optical information recording medium, comprisinga photosensitive recording film whose optical characteristics are changed by laser beam irradiation,

wherein an area where a width of a mark that is formed on the photosensitive recording film by the laser beam irradiation is constant and a space area where the width is zero each are defined as a unit recording area, and

amounts of correction of leading and trailing edge positions of a recording pulse for recording the unit recording area other than the space area that are determined by a width of the unit recording area to be recorded are recorded previously on a predetermined area as information.

14. An optical information recording apparatus for recording information on an optical information recording medium,

the optical information recording medium being irradiated with a laser beam having a plurality of powers while switching the power of the laser beam to cause a change in optical characteristics of a photosensitive recording film so that a mark is formed,

wherein an area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area, and information is represented by at least three different widths of the unit recording areas,

the apparatus comprising:

a modulation means for modulating recording information to provide modulated information;

a multi-valued means for converting the modulated information to multi-valued information;

a recording pulse generation means for generating a recording pulse based on the multi-valued information;

a recording power control means for controlling a recording power in accordance with a width of the unit recording area to be recorded that corresponds to the multi-valued information;

an edge position correction means for correcting leading and trailing edge positions of the recording pulse in accordance with the width of the unit recording area to be recorded; and

a recording means for recording the information on the optical

information recording medium by irradiation of the laser beam based on the recording power and the corrected recording pulse.

15. The optical information recording apparatus according to claim 14, wherein the edge position correction means corrects the leading and trailing edge positions of the recording pulse in accordance with a combination of a width and a length of the unit recording area to be recorded.

16. The optical information recording apparatus according to claim 15, wherein the edge position correction means corrects the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the preceding unit recording area and the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a length thereof and a length of the next unit recording area.

17. An optical information recording apparatus for recording information on an optical information recording medium,

the optical information recording medium being irradiated with a laser bean having a plurality of powers while switching the power of the laser beam to cause a change in optical characteristics of a photosensitive recording film so that a mark is formed,

wherein an area in the mark where a width of the mark is constant and a space area where the width is zero each are defined as a unit recording area, and information is represented by at least three different widths of the unit recording areas,

the apparatus comprising:

a modulation means for modulating recording information to provide modulated information;

a multi-valued means for converting the modulated information to multi-valued information;

a recording pulse generation means for generating a recording pulse based on the multi-valued information;

a recording power control means for controlling a recording power in accordance with a width of the unit recording area to be recorded that corresponds to the multi-valued information;

an edge position correction means for correcting a leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded and a width of the preceding unit recording area and for correcting a trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded and a width of the next unit recording area; and

a recording means for recording the information on the optical information recording medium by irradiation of the laser beam based on the recording power and the corrected recording pulse.

18. The optical information recording apparatus according to claim 17, wherein the edge position correction means corrects the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area and a length of the unit recording area to be recorded, and the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the next unit recording area and a length of the unit recording area to be recorded.

19. The optical information recording apparatus according to claim 18, wherein the edge position correction means corrects the leading edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the preceding unit recording area, a length of the unit recording area to be recorded and a length of the preceding unit recording area, and the trailing edge position of the recording pulse in accordance with a combination of a width of the unit recording area to be recorded, a width of the next unit recording area, a length of the unit recording area to be recorded and a length of the next unit recording area.

ABSTRACT

An edge position correction circuit corrects the edge positions of a recording pulse according to multi-valued information that determines the width of a mark. This allows the mark edges to be formed at the precise positions. Therefore, even if the mark having any width is recorded, multi-valued information can be recorded/reproduced accurately.

Inventor: Narumi et al.
Docket No.: 10873.771USWO
Title: OPTICAL INFORMATION RECORDING METHOD....
Attorney Name. Douglas P. Mueller
Phone No.: 612.371.5237

09/980109

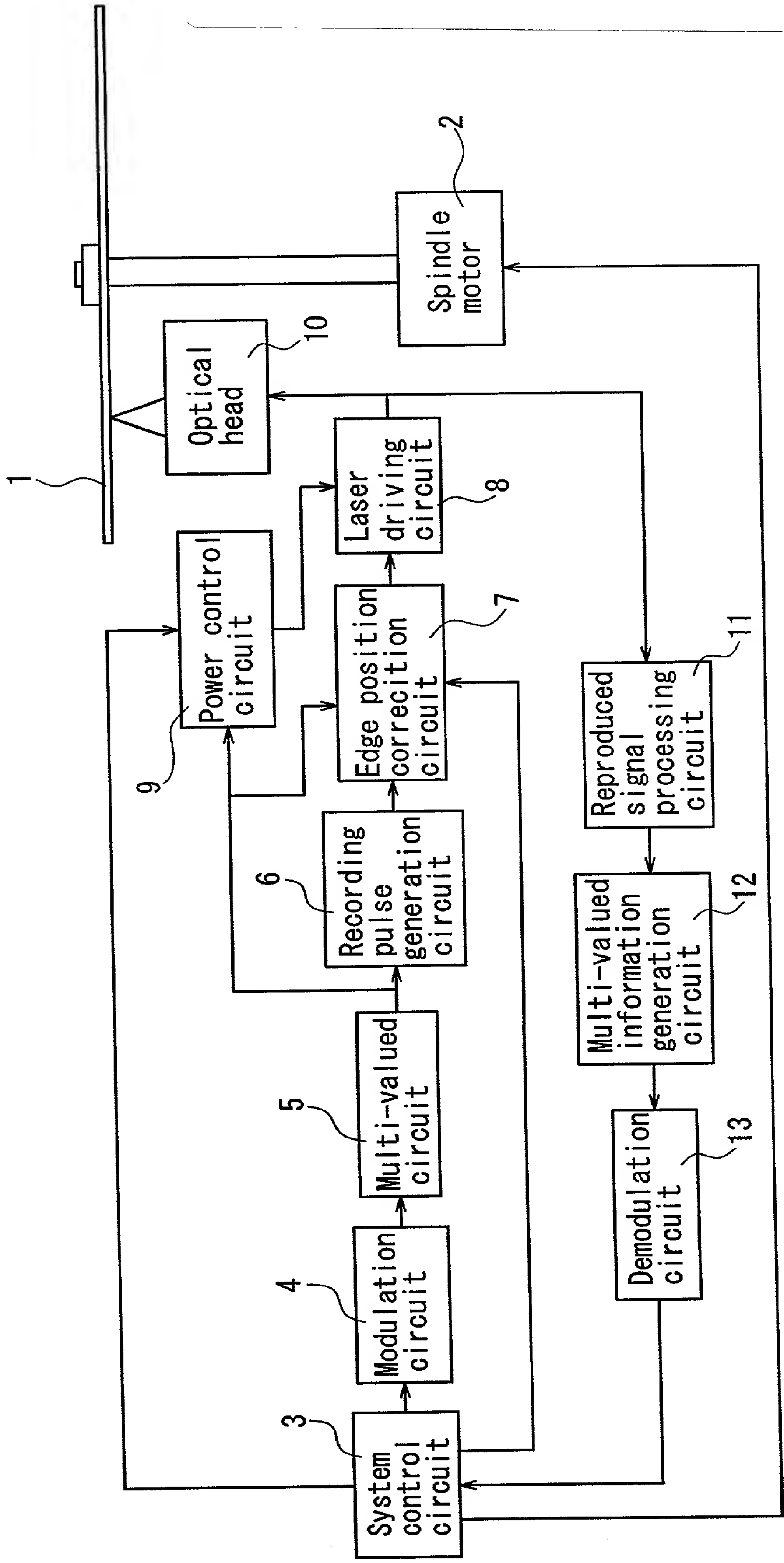
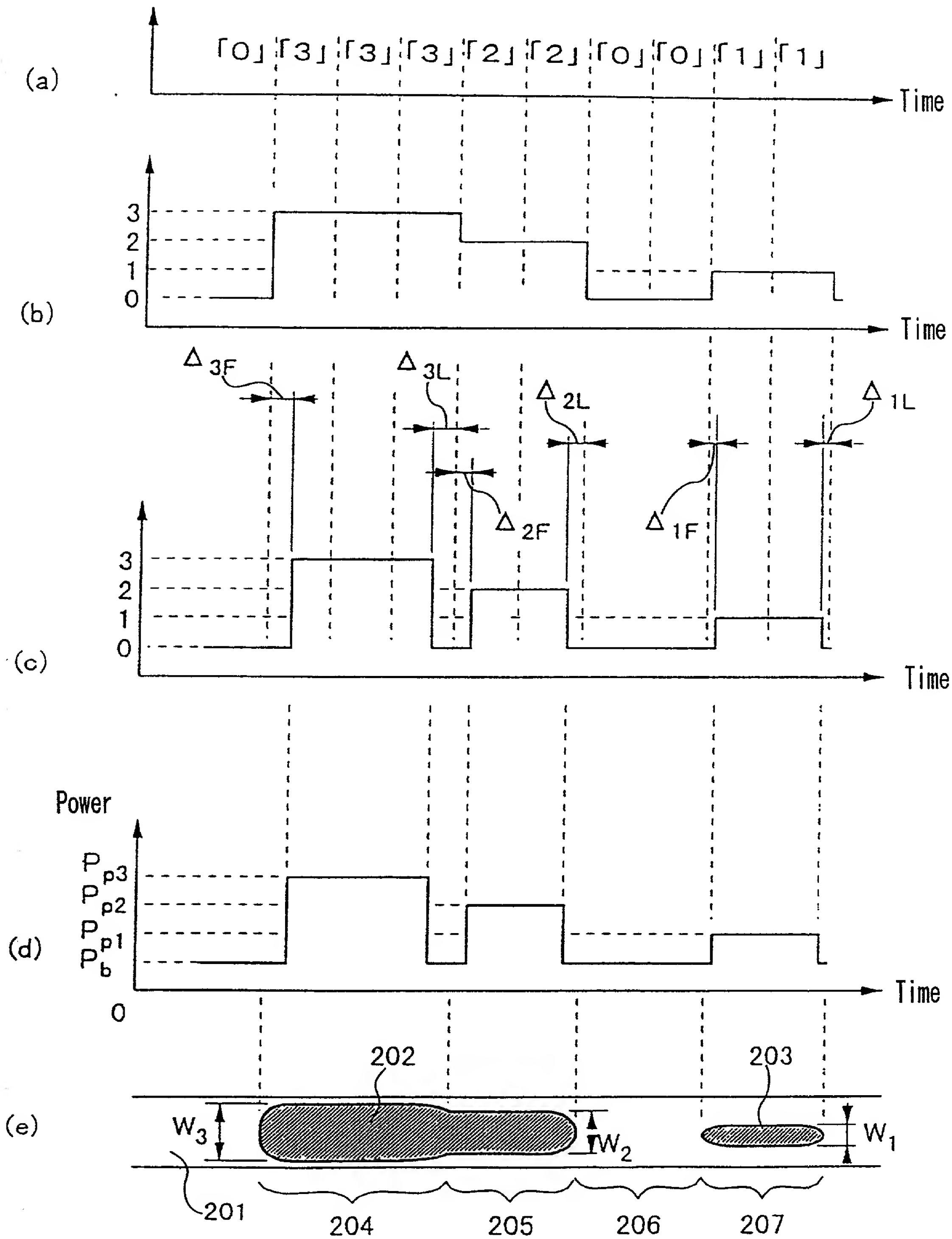


FIG. 1

09/980109



F I G. 2

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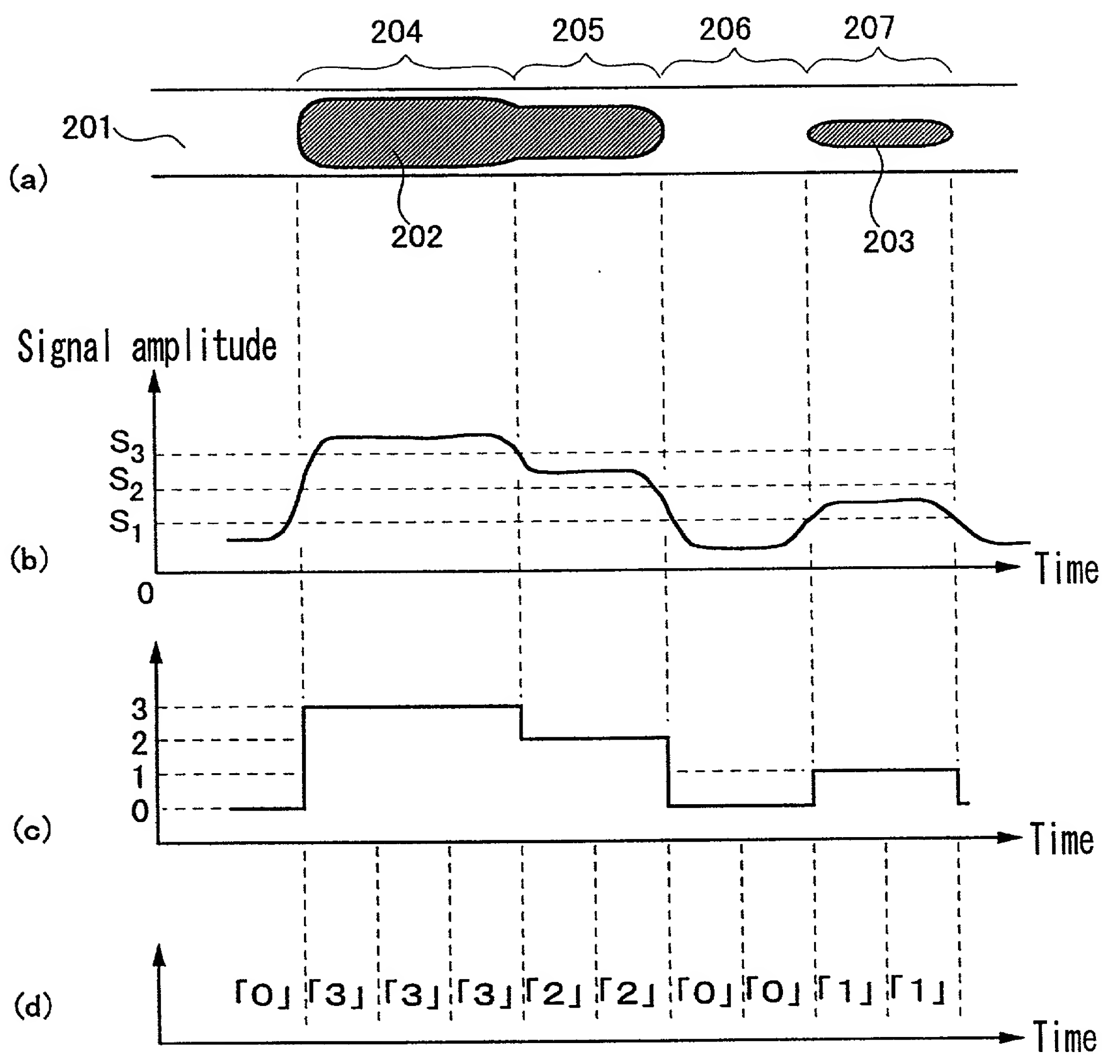

F I G. 3

Inventor: Narumi et al.
Docket No.: 10873.771USWO
Title: OPTICAL INFORMATION RECORDING METHOD ...
Attorney Name: Douglas P. Mueller
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Sheet 4 of 7

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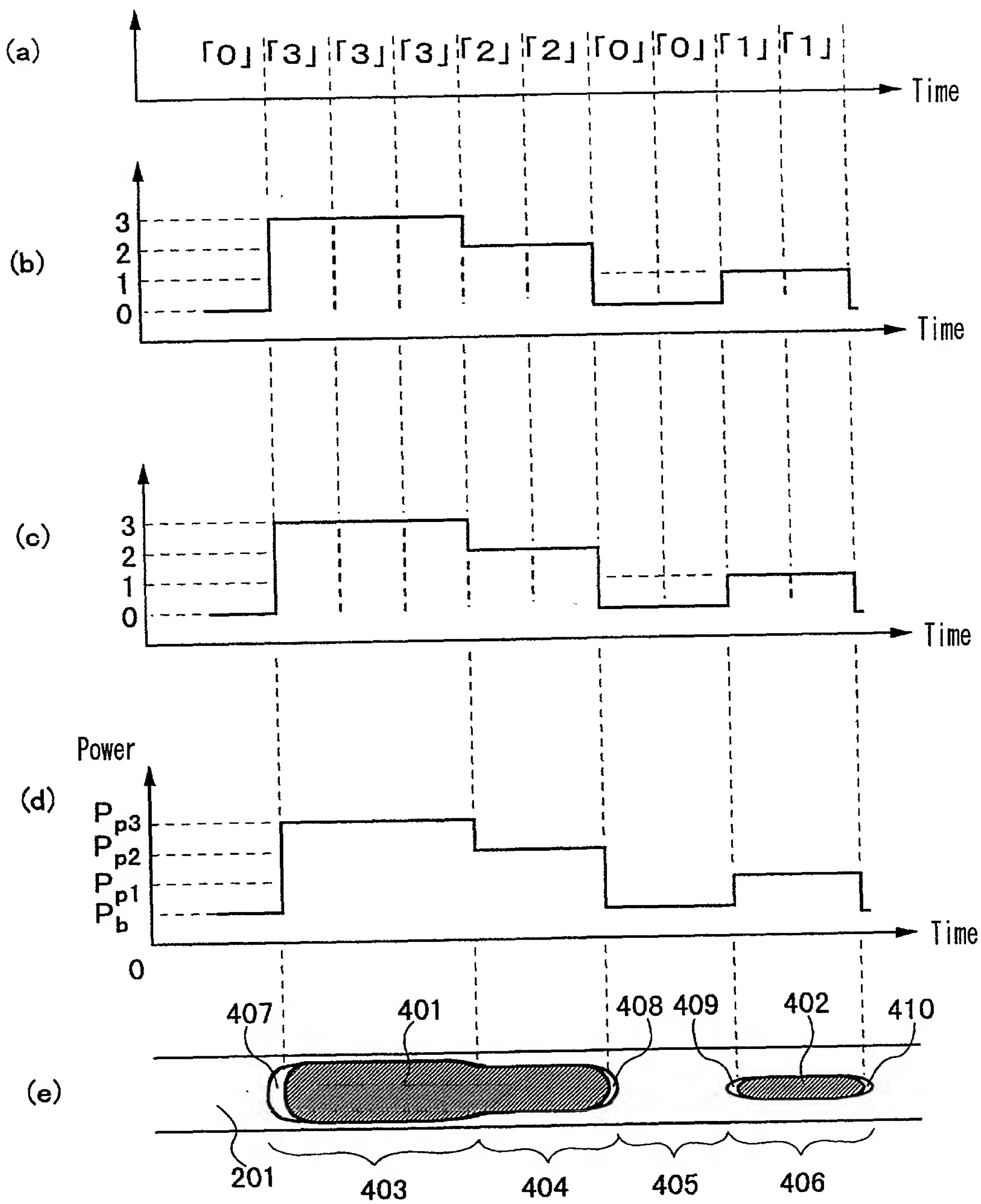
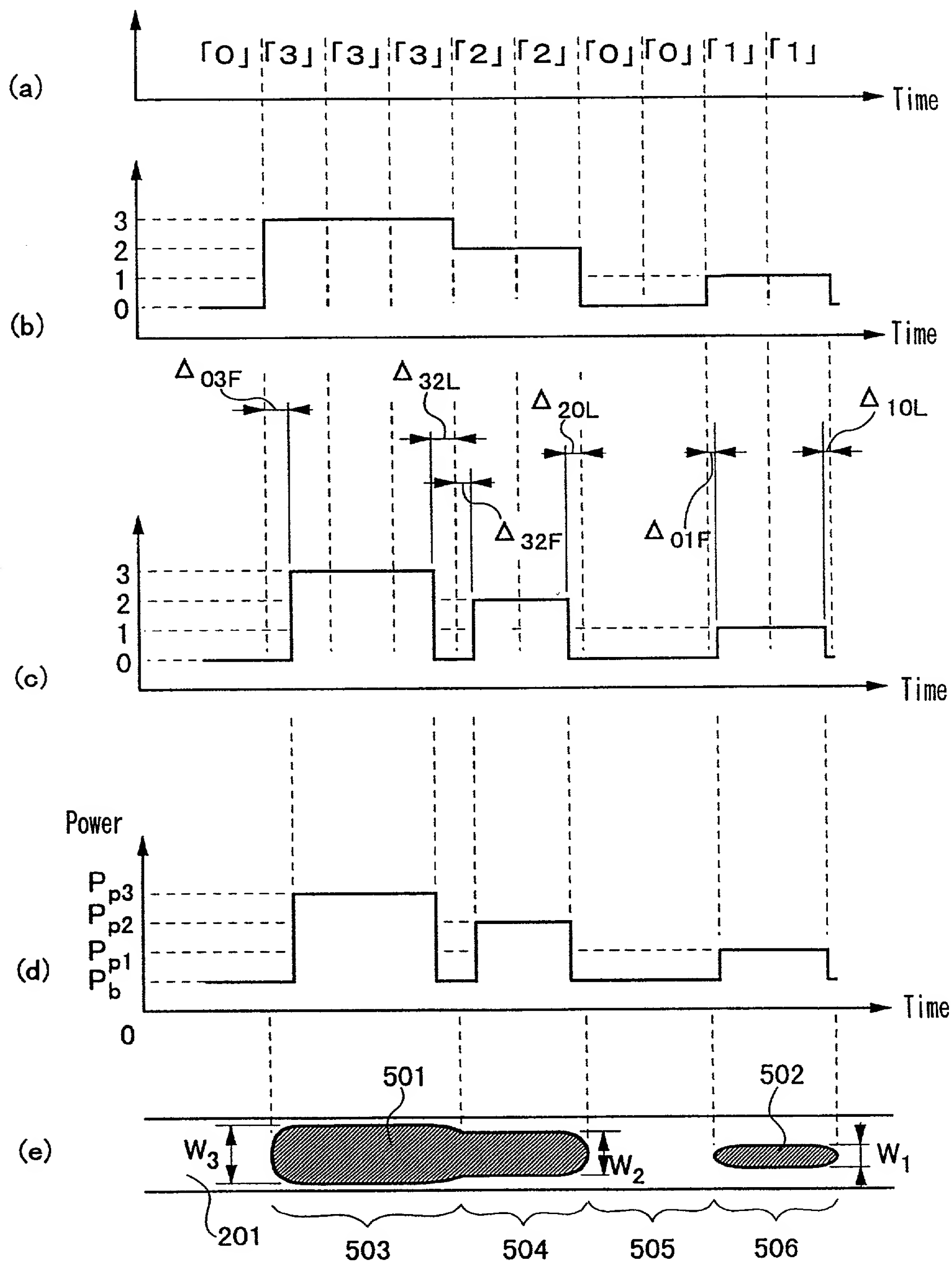


FIG. 4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Δ 32L
Δ 20L
Δ 10L
Δ 32F
Δ 01F
(c)
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2
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Time
Power
P_{p3}
P_{p2}
P_{p1}
P_b
(d)
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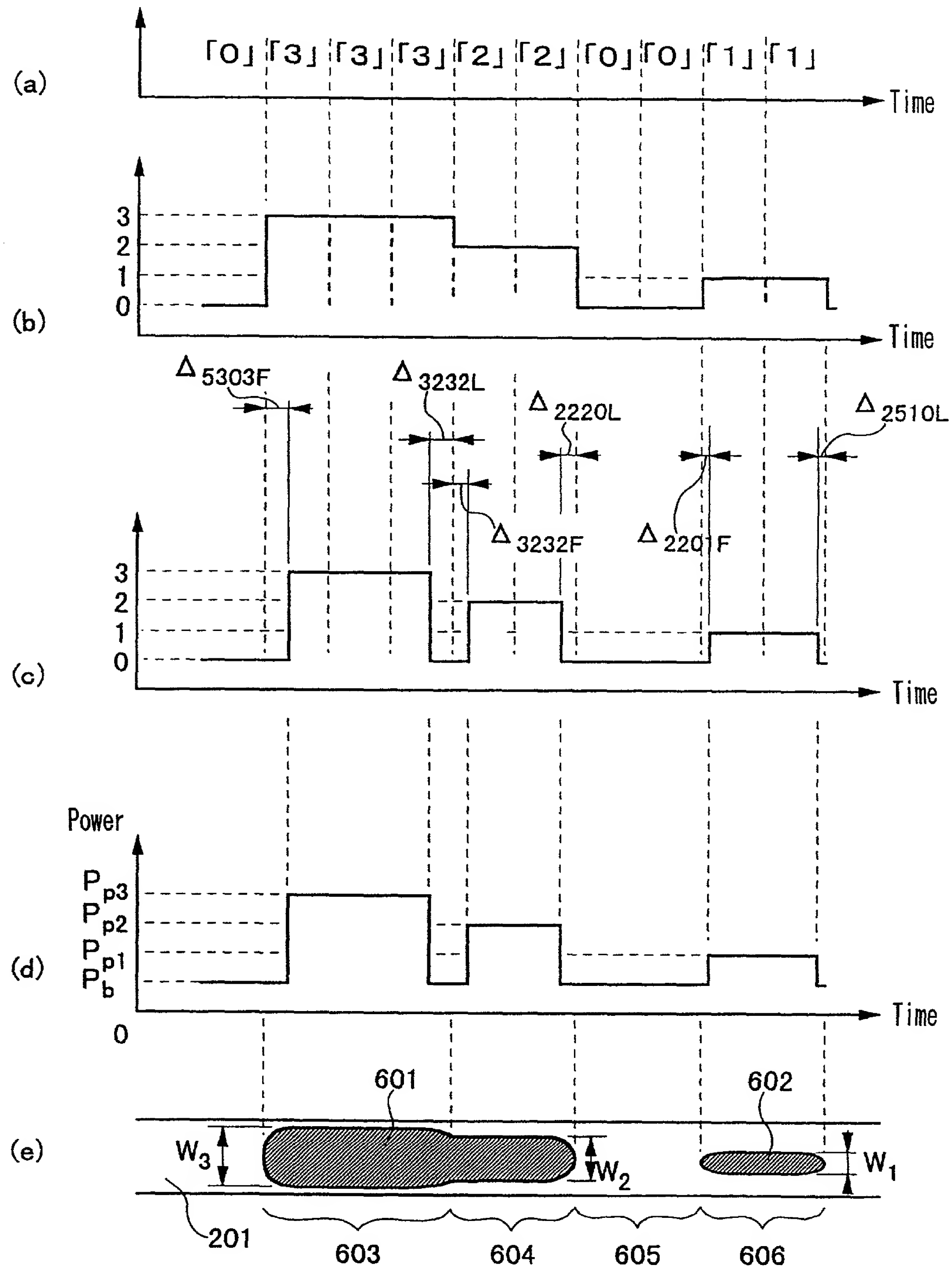
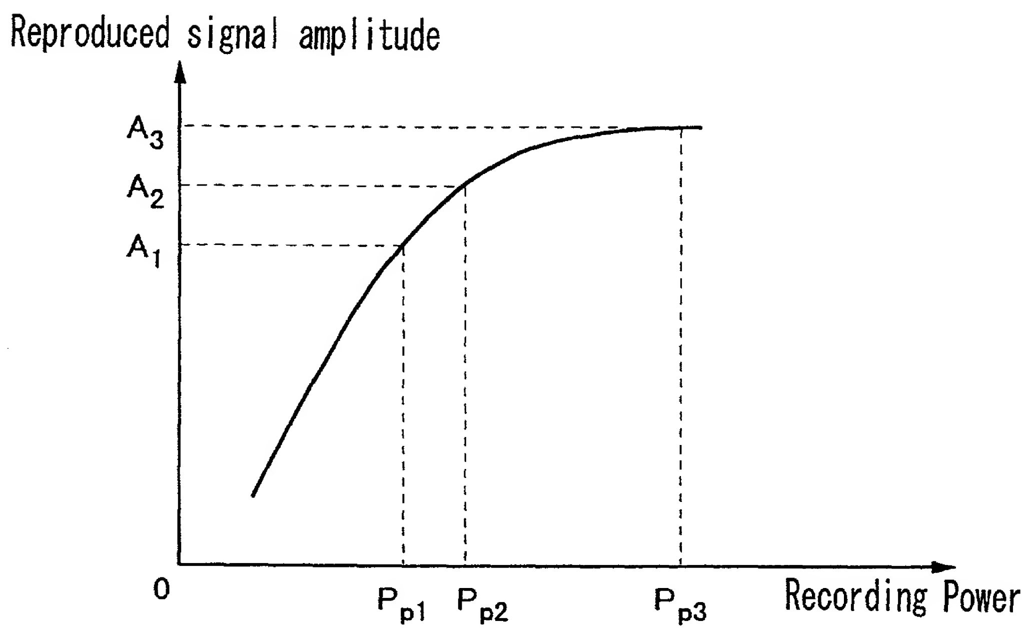
F I G. 5

09/980109



F I G. 6


Reproduced signal amplitude
A3
A2
A1
0
Pp1
Pp2
Pp3
Recording Power

F I G. 7

Attorney Docket No. 10873.771USWO

MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: OPTICAL INFORMATION RECORDING METHOD, OPTICAL INFORMATION RECORDING APPARATUS AND OPTICAL INFORMATION RECORDING MEDIUM

The specification of which
a. ☐ is attached hereto
b. ☒ was filed on as application serial no. and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. PCT/JP00/03480 filed May 30, 2000 and as amended on (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

a. ☐ no such applications have been filed.
b. ☒ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**
Japan	11-152469	31 May 1999	
ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	**DATE OF FILING (day, month, year)**	**STATUS (patented, pending, abandoned)**

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	**DATE OF FILING (Day, Month, Year)**

I acknowledge the duty to disclose information that is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (reprinted below):

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

(e) In any continuation-in-part application, the duty under this section includes the duty to disclose to the Office all information known to the person to be material to patentability, as defined in paragraph (b) of this section, which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

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Knearl, Homer L.	Reg. No. 21,197
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Kowalchyk, Katherine M.	Reg. No. 36,848
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I understand that the execution of this document, and the grant of a power of attorney, does not in itself establish an attorney-client relationship between the undersigned and the law firm Merchant & Gould P.C., or any of its attorneys.

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23552
PATENT TRADEMARK OFFICE

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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